DOCUMENT RESUME

ED 124 588 TM 005 345

AUTHOR	Hunter, David R.
TITLE	Development of An Enlisted Psychomotor/Perceptual Test Battery. Final Report.
INSTITUTION	Air Force Human Resources Lab., Lackland AFB, Tex. Personnel Research Div.
SPONS AGENCY	Air Force Human Resources Lab., Brooks AFB, Texas.
REPORT NO	AFHRL-TR-75-60
PUB DATE	Nov 75
NOTE	46p.
EDRS PRICE	MF-$0.83 HC-$2.06 Plus Postage.
DESCRIPTORS	*Ability; Associative Learning; *Comparative Analysis; Computer Oriented Programs; *Enlisted Personnel; Factor Analysis; Kinesthetic Perception; Memory; *Perception Tests; Performance Tests; Predictive Validity; Psychometrics; *Psychomotor Skills; Test Reliability; Tests
IDENTIFIERS	*Air Force

ABSTRACT

It may be possible, using assessments of motor and perceptual skills which are largely independent of ethnic and educational background, to admit to the military individuals who would be rejected on the basis of their paper-and-pencil test scores, but who through their performance on non-verbal measures, can be identified as highly likely to succeed in certain careers. For this reason, a battery of seven tests was developed to measure kinesthetic memory, perceptual speed, performance under stress, associative learning, immediate and delayed memory, concept identification, and performance under divided attention. To determine the factor structure and the psychometric characteristics of the battery, 21 paper-and-pencil tests were administered to a sample of airmen. The measures from the psychomotor/perceptual battery were generally highly reliable. Factor analyses resulted in the identification of six factors specific to the psychomotor/perceptual battery, four to the paper-and-pencil measures, and one factor common to both batteries. Further, the sample was divided into upper and lower groups based on Armed Forces Qualification Tests (AFQT) scores. Their performance on the paper-and-pencil and psychomotor/perceptual batteries was compared and differences evaluated for statistical significance. The differences between the groups were generally much smaller on the psychomotor/perceptual tests than on the paper-and-pencil measures. (EVH)

****
* Documents acquired by ERIC include many informal unpublished *
* materials not available from other sources. ERIC makes every effort *
* to obtain the best copy available. Nevertheless, items of marginal *
* reproducibility are often encountered and this affects the quality *
* of the microfiche and hardcopy reproductions ERIC makes available *
* via the ERIC Document Reproduction Service (EDRS). EDRS is not *
* responsible for the quality of the original document. Reproductions *
* supplied by EDRS are the best that can be made from the original. *
****

AFHRL-TR-75-60

AIR FORCE

HUMAN RESOURCES

LABORATORY

ED124588

U S DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

THIS DOCUMENT HAS BEEN REPRODUCED EXACTLY AS RECEIVED FROM THE PERSON OR ORGANIZATION ORIGINATING IT. POINTS OF VIEW OR OPINIONS STATED DO NOT NECESSARILY REPRESENT OFFICIAL NATIONAL INSTITUTE OF EDUCATION POSITION OR POLICY

DEVELOPMENT OF AN ENLISTED PSYCHOMOTOR/PERCEPTUAL TEST BATTERY

By

David R. Hunter

PERSONNEL RESEARCH DIVISION
Lackland Air Force Base, Texas 78236

November 1975
Final Report for Period June 1972 – July 1975

Approved for public release: distribution unlimited.

TM005 345

AIR FORCE SYSTEMS COMMAND
BROOKS AIR FORCE BASE, TEXAS 78235

NOTICE

When US Government drawings, specifications, or other data are used for any purpose other than a definitely related Government procurement operation, the Government thereby incurs no responsibility nor any obligation whatsoever, and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise, as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This final report was submitted by Personnel Research Division, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas 78236, under project 7719, with Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235.

This report has been reviewed and cleared for open publication and/or public release by the appropriate Office of Information (OI) in accordance with AFR 190-17 and DoDD 5230.9. There is no objection to unlimited distribution of this report to the public at large, or by DDC to the National Technical Information Service (NTIS).

This technical report has been reviewed and is approved.

LELAND D. BROKAW, Technical Director
Personnel Research Division

Approved for publication.

HAROLD E. FISCHER, Colonel, USAF
Commander

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: AFHRL-TR-75-60
2. GOVT ACCESSION NO.:
3. RECIPIENT'S CATALOG NUMBER:

4. TITLE (and Subtitle): DEVELOPMENT OF AN ENLISTED PSYCHOMOTOR/ PERCEPTUAL TEST BATTERY

5. TYPE OF REPORT & PERIOD COVERED: Final, June 1972 – July 1975

6. PERFORMING ORG. REPORT NUMBER:

7. AUTHOR(s): David R. Hunter

8. CONTRACT OR GRANT NUMBER(s):

9. PERFORMING ORGANIZATION NAME AND ADDRESS: Personnel Research Division, Air Force Human Resources Laboratory, Lackland Air Force Base, Texas 78236

10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS: 62703F, 77191506

11. CONTROLLING OFFICE NAME AND ADDRESS: Hq Air Force Human Resources Laboratory (AFSC), Brooks Air Force Base, Texas 78235

12. REPORT DATE: November 1975

13. NUMBER OF PAGES: 46

14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office):

15. SECURITY CLASS. (of this report): Unclassified

15a. DECLASSIFICATION/DOWNGRADING SCHEDULE:

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

Test batteries and apparatus developed by BioTechnology, Inc., under contract F41609-72-C-0043.

SMA studies: 5128, 5325, 5364

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

psychomotor tests
perceptual tests
performance tests
low-ability airmen
test battery
psychological testing

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

A battery of seven psychomotor/perceptual tests, developed by Biotechnology, Incorporated, of Falls Church, Virginia, was administered to 380 airmen assigned to the 3701 Personnel Processing Squadron at Lackland Air Force Base, Texas. A paper-and-pencil battery of 21 tests was also administered to the airmen.

The objectives of the project were to determine the psychometric characteristics of the psychomotor/ perceptual battery and to compare the performance of "high" and "low" ability airmen (as determined by Armed Forces Qualification Test scores).

(Over)

Item 20 Continued:

Analysis of the data indicated that the measures obtained from the psychomotor/perceptual battery were generally highly reliable. Factor analyses resulted in the identification of six factors that were specific to the psychomotor/perceptual battery, four factors that were specific to the paper-and-pencil measures, and one factor that was common to both batteries.

The sample of subjects was divided into upper and lower groups based upon AFQT scores. The performance of the upper and lower groups on the paper-and-pencil and psychomotor/perceptual batteries was compared and differences evaluated for statistical significance. It was found that the differences between the upper and lower groups were generally much smaller on the psychomotor/perceptual tests than on the paper-and-pencil measures.

Recommendations for subsequent research and development are given.

PREFACE

This work was performed under Project 7719, Air Force Personnel Systems Development on Selection, Assignment, Evaluation, Quality Control, Retention, Promotion, and Utilization; Task 771915, Development of Perceptual-Psychomotor Measures for Air Force Enlisted Programs.

The development of the tests and modifications of the testing apparatus were carried out under the provisions of Contract Number F41609-72-C-0043 by BioTechnology, Inc. Dr. James F. Parker, Jr. was the principal investigator for BioTechnology, and Dr. Lonnie D. Valentine acted as contract monitor for the Personnel Research Division, Air Force Human Resources Laboratory.

The author expresses his appreciation to Airman Vince Maurelli and Airman Louis Kaluza for their valuable aid in the data collection phases of this research and to Mr. James Sanders, of BioTechnology, Inc., for his role in the programming of the tests and modifications of the testing apparatus.

TABLE OF CONTENTS

	Page
I. Introduction	5
II. Battery Design and Implementation	5
III. Test Descriptions	10
Psychomotor/Perceptual Battery	10
Paper-and-Pencil Reference Measures	12
IV. Subject Testing	13
V. Data Analysis	13
VI. Results and Discussion	18
VII. Conclusions and Recommendations	19
References	19
Appendix A Supplementary Technical Data	21

LIST OF ILLUSTRATIONS

Figure		Page
1	Test administrator's station	6
2	Subject's test console	7
3	Subjects' response panel and display screen	8
4	Diagram of testing system	9
A1	Toggle switch geometric figures	37
A2	Keyboard geometric figures and novel figures	41
A3	Geometric figures used in Test 6 concept identification	43

LIST OF TABLES

Table		Page
1	Reliability Estimates for Tests Contained in the Psychomotor/Perceptual Battery	14
2	Rotated Factors, Psychomotor/Perceptual Battery	15
3	Rotated Factors, Combined Psychomotor/Perceptual and Reference Paper-and-Pencil Batteries	16
4	Comparison of Total, Upper and Lower Groups, on All Measures	17
A1	Correlations Among Psychomotor/Perceptual and Paper-and-Pencil Measures	22
A2	Factor Loadings, Psychomotor/Perceptual Battery	24
A3	Factor Loadings, Combined Psychomotor/Perceptual and Reference Paper-and-Pencil Batteries	25
A4	Stimuli Presentation Order for Test 1	35
A5	Stimuli Presentation Order for Test 2	36
A6	Stimuli Presentation Order for Test 3	36
A7	Stimuli Presentation Order for Test 4, Part 1	38
A8	Stimuli Presentation Order for Test 4, Part 2	39
A9	Stimuli Presentation Order for Test 5, Part 1	40
A10	Stimuli Presentation Order for Test 5, Part 2	40
A11	Stimuli Presentation Order for Test 6	42

DEVELOPMENT OF AN ENLISTED PSYCHOMOTOR/PERCEPTUAL TEST BATTERY

I. INTRODUCTION

As the Air Force proceeds in the all-volunteer era, assessment of the individual's motor and perceptual skills may become increasingly important and useful in selecting and assigning those applicants for enlistment to Air Force jobs which best fit their abilities. This will be especially true as it becomes necessary to select from among less well educated, culturally deprived, and minority group applicants. Applicants from these groups typically perform less well on conventional paper-and-pencil selection measures, as compared to the majority of the population. It may be possible, using assessments of motor and perceptual skills which are largely independent of ethnic and educational background, to admit to the service individuals who would be rejected on the basis of their paper-and-pencil test scores, but who, through their performance on these non-verbal measures, can be identified as highly likely to succeed in certain career areas.

Previous research in this area has been conducted by the University of Alabama (McLaurin, 1973) under contract from the Personnel Research Division, Air Force Human Resources Laboratory (AFHRL), Lackland Air Force Base, Texas. In that study a battery of nine performance tests were developed and validated against the course grades for a sample of airmen attending the Aerospace Ground Equipment Repairman course at Chanute Air Force Base, Illinois. Analysis of the results of that study indicated that the scores from the performance battery made a significant contribution to the Electronics Aptitude Index in predicting course grade and, for most course grades, the performance tests were equal in validity to the Selector Index.

The purpose of the present effort was to design and develop a battery of perceptual and psychomotor measures suitable for use with the test equipment already acquired by the Personnel Research Division, basing these measures, in part, on the results of the University of Alabama study. A prime consideration in the design of this battery was the minimization of literacy requirements in an effort to assure greater opportunity for predictive validity unique to that achievable with paper-and-pencil tests. Therefore, it was not considered necessary or desirable to exactly replicate the measures used in the University of Alabama study, which used both letters and digits as stimuli, but rather to use the basic concepts developed in that study as a guide in the formulation of new measures.

II. BATTERY DESIGN AND IMPLEMENTATION

A contract was established with BioTechnology, Incorporated, of Falls Church, Virginia, for the design of the test battery, the programming of the PDP-8/L minicomputer for the administration of the battery, and for required modifications and additions to the existing test system. These modifications included the fabrication and installation of new subject response panels containing the switches and buttons which the subject would use in responding to test stimuli, and the alteration of the test administrator's station to allow for improved monitoring of the subjects' actions.

The test administrator's station and one of the two subject consoles are shown in Figures 1 and 2, respectively. The subject's response panel and display screen (showing a typical display) are depicted in Figure 3. The two subject response panels are identical and a screen is provided between the subject consoles to prevent observation of one subject by the other. A diagram of the testing system components showing the relationship among the various devices is given in Figure 4.

The computer program for the administration of the test battery provides for simultaneous testing of two subjects. Each subject can proceed through a test independent of the actions of the other subject; however, it is necessary to have both subjects start each test simultaneously. This restriction is necessitated by the use of a single cartridge tape player, controlled by the computer, which is used to give the subjects their instructions at the start of each test.

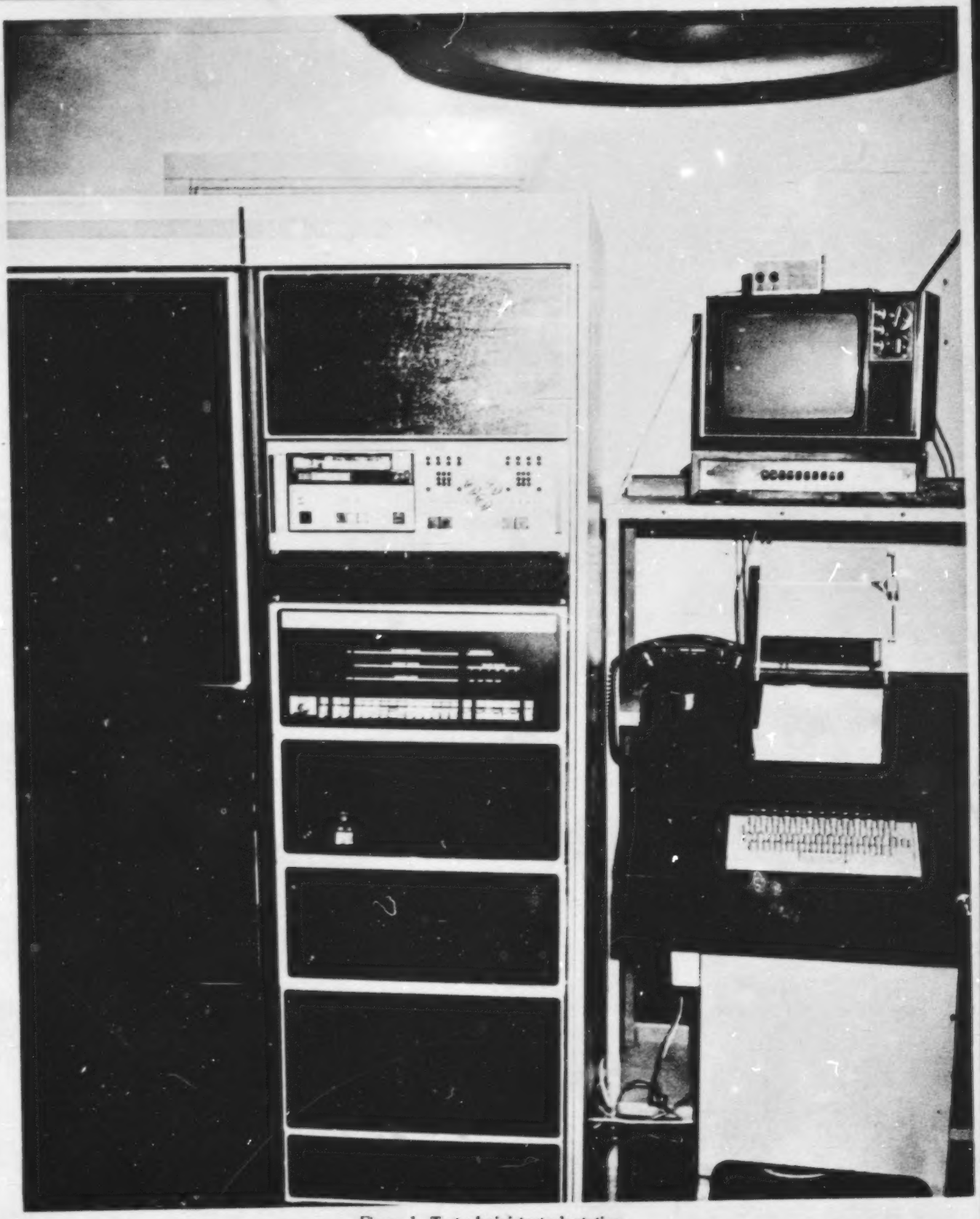

Figure 1. **Test administrator's station.**

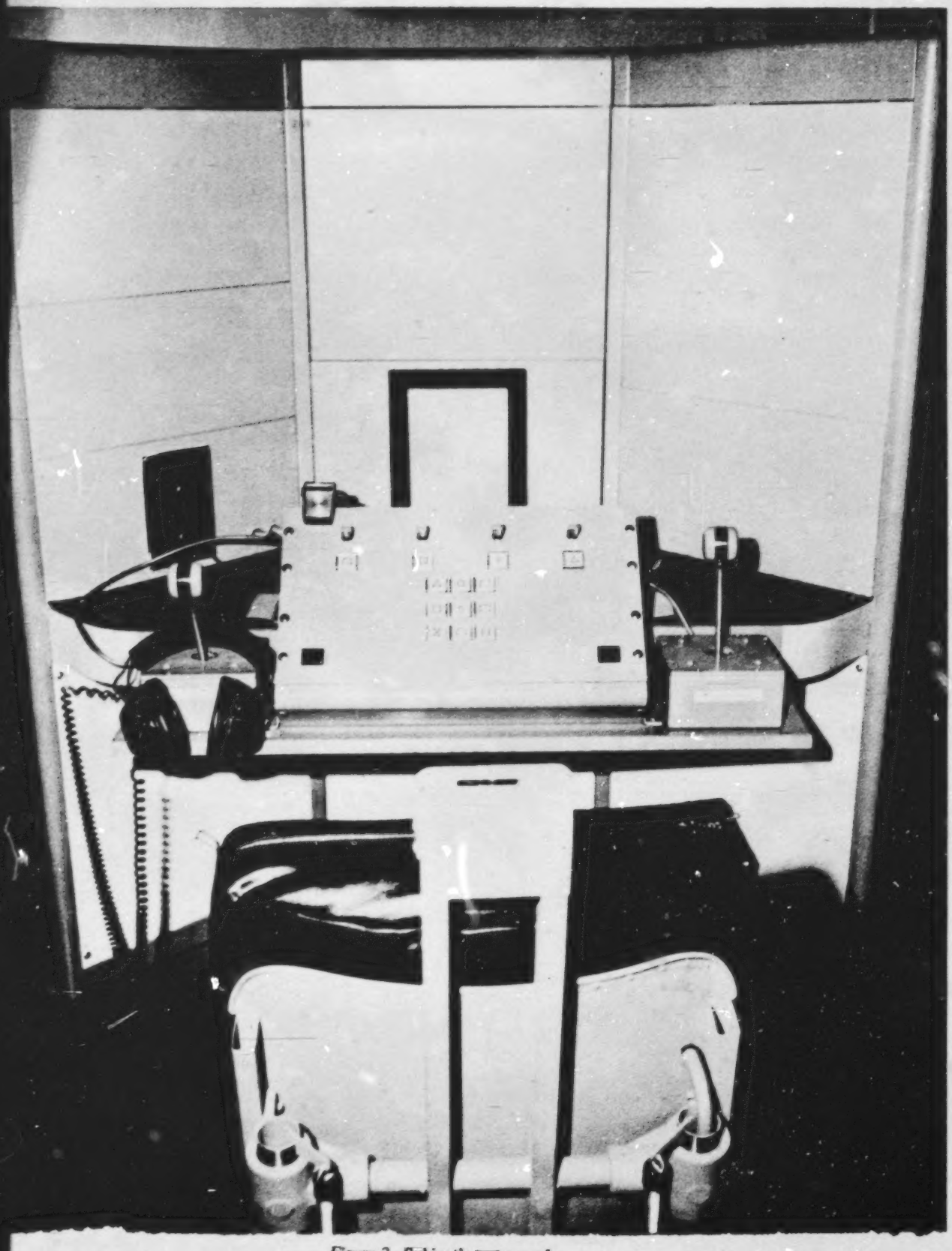

Figure 2. **Subject's test console.**

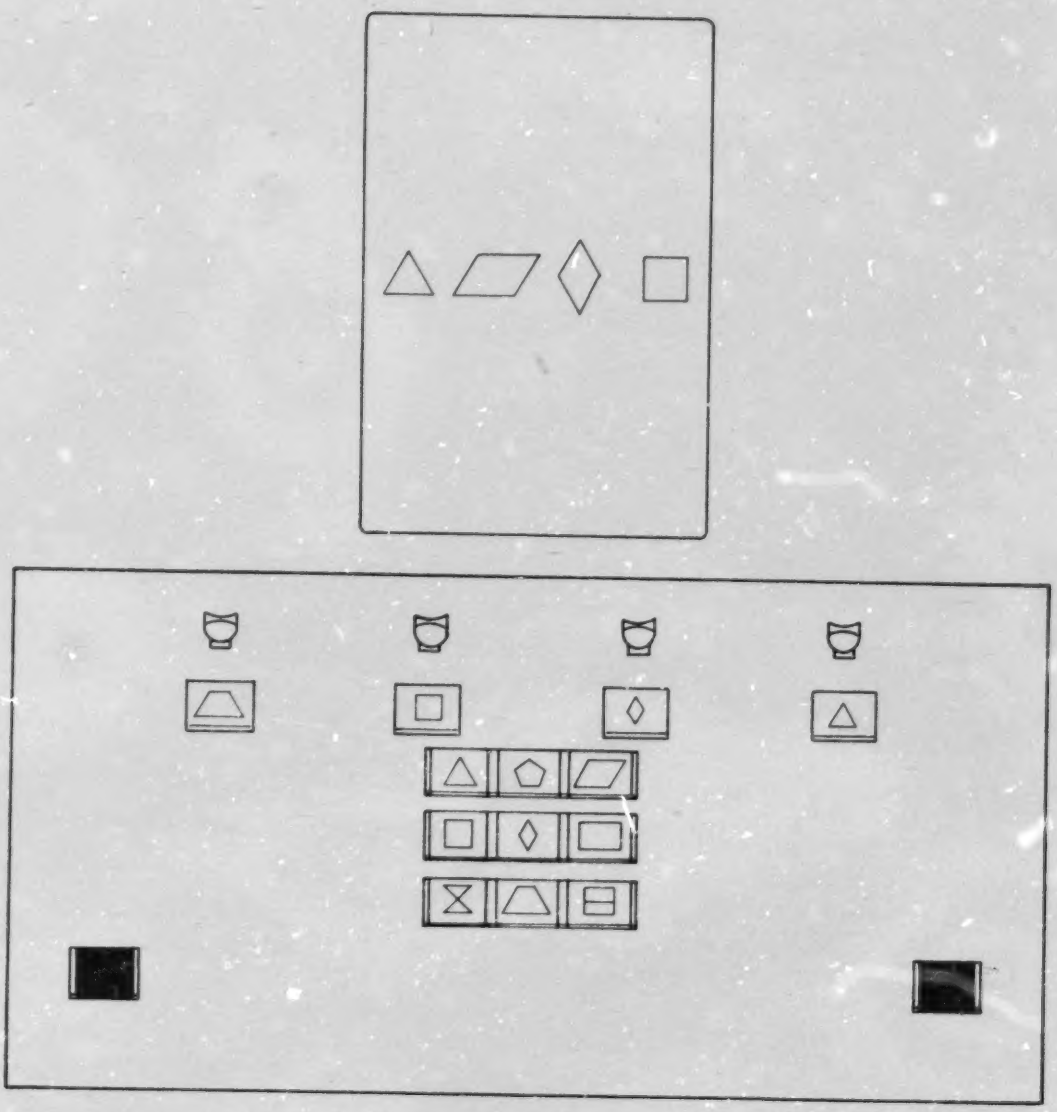

Figure 3. Subjects' response panel and display screen.

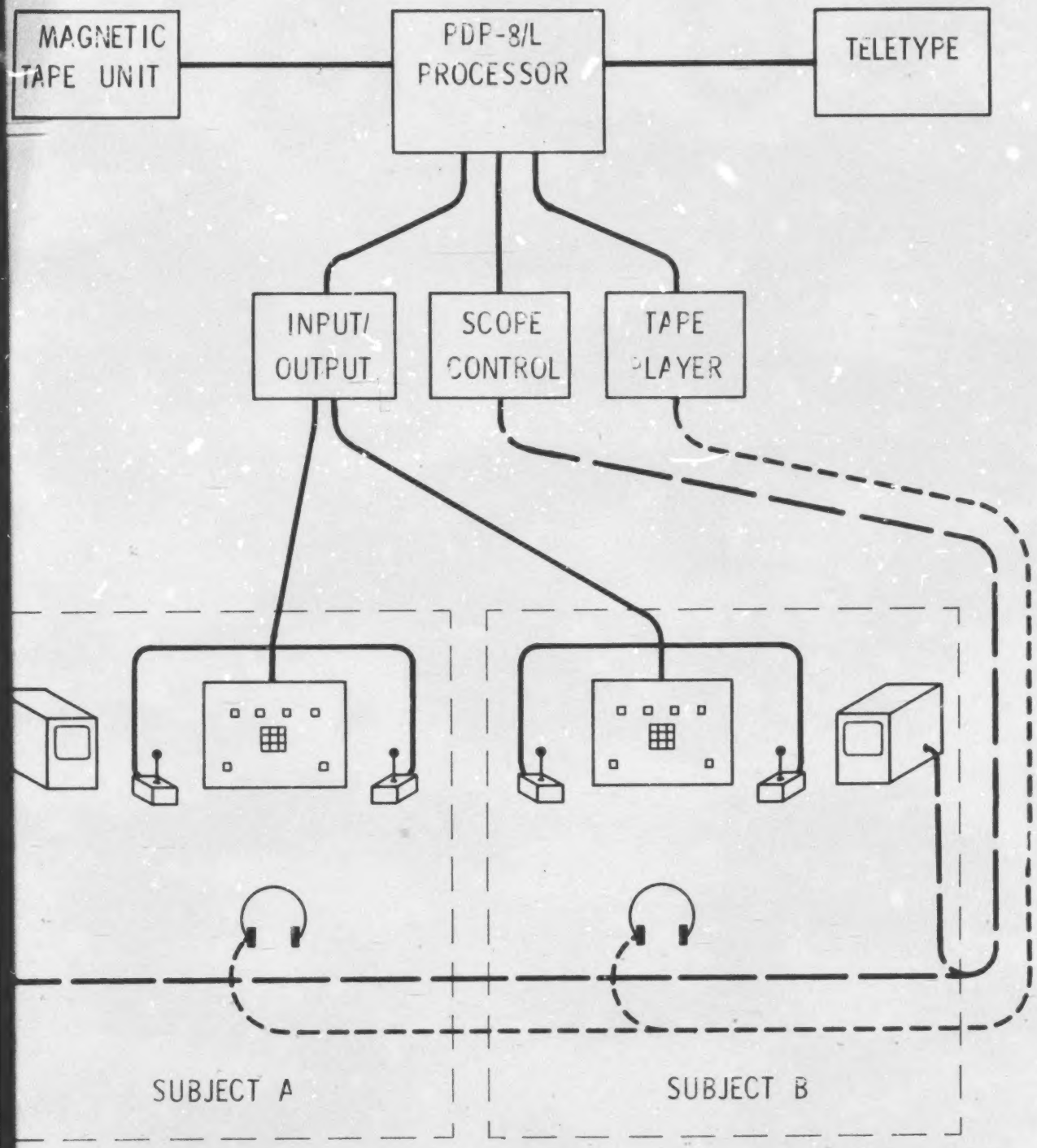

Figure 4. **Diagram of testing system.**

Scoring and storage of all subject responses are handled entirely by the computer. Printouts of the subjects' scores are given at the end of each test along with a punched paper tape containing the subjects' scores for each item in the test. This paper tape is later used to transfer the subjects' scores to magnetic tape, allowing direct compatibility with the larger computer system used for data analysis, and thus avoids the necessity for keypunching of data – a process that is time-consuming and often introduces errors into the data files through operator error.

Acting under the guidelines set out in the contract as to the measures to be included in the battery, the contractor designed and programmed a battery consisting of seven tests. These tests, in the order in which they are given in the battery, are described in the following section, along with a brief description of the paper-and-pencil tests administered to the subjects for reference purposes.

III. TEST DESCRIPTIONS[1]

Psychomotor/Perceptual Battery

Test 1. Kinesthetic Memory – requires that the subject learn a sequence of switch manipulations and then repeat those manipulations while wearing opaque goggles. The subject is shown four geometric figures arranged in a horizontal line across the screen. The subject is instructed to pull down the toggle switch that is associated with each of the figures, in the order in which they appear on the screen (left to right). Before initiating the switch pulling and after completion of the response, the subject is required to keep two "home" keys pressed down. These are the dark keys shown in (Figure 2) the lower-right and -left corners of the response panel. Release of one of these buttons, when the subject initiates his response, causes the screen to be erased so that he cannot use it for reference while performing the task. The subject receives twelve learning trials in which the order of the figures across the screen is always the same, and in which a bell tone accompanies the onset of the stimulus. After completion of these learning trials, the subject is instructed to put on a pair of opaque goggles so that he is no longer able to see the response panel. After he has done so, he is told to repeat the switch activation sequence every time he hears the bell tone. Twelve trials are given in this condition. The measures obtained are (1) Correct Answers – the number of times he correctly completes the switch activation sequence while wearing the goggles, and (2) Response Time, which is the time required for the completion of each of the blind trials measured from release of one of the "home" buttons to completion of the activation sequence.

Test 2. Perceptual Speed – presents the subject with four geometric figures arrayed across the screen as in Test 1. However, in this test the ordering of the figures across the screen is quasi-random, so that no presentation is identical to the preceeding one. The subject is given two practice trials followed by twenty scored trials. In addition to the Correct Answers and Response Time measures described for Test 1, a measure called Perception Time is also obtained. This is the length of time that the subject studies the display before initiating his response, measured from onset of the stimulus presentation to release of one of the "home" keys.

Test 3. Performance Under Stree – is very similar to Test 2, except that some of the figures in the stimulus are shaded. The subject is instructed to pull down the toggle switch associated with unshaded figures, as he did in Test 2, and to push up the toggle switch associated with shaded figures. To increase the subject's stress level, an audio tape recording of compressed tower-to-aircraft communications is played during the test. No responses to these messages are required of the subject, and he is instructed to ignore them as much as he can. Two practice trials are given followed by twenty scored trials. The measures obtained are the same as in Test 2.

Test 4. Associative Learning – uses the keyboard located in the center of the panel. The subject is shown some of the figures on the keyboard paired with "stick figure" drawings of common objects (i.e., table, man, board, etc.) or novel geometric figures, and is instructed to learn the pairings. Each pair of

[1]Complete descriptions of the test procedures – including instruction to the subjects, computer operation, test administrator's actions and listings of all stimuli used in each test – are contained in Appendix A.

figures is shown to the subject three times. During Part 1 of this test the pairs of figures are displayed for two seconds per presentation during the learning trials. After being given the learning trials, the subject is then shown each of the stimulus figures one at a time and is instructed to press the keyboard button figure that was paired with the figure on the screen. One recall trial is given for each of the eight stimulus figures used.

Part 2 of the test is identical to Part 1, except that the presentation time of the pairs of figures in the learning phase is changed to one/half second. Eight new stimulus figures are used and, as in part 1, twenty-four learning trials are followed by eight recall trials. The measures obtained from both parts of this test are Correct Answers, which is the number of times the subject responds to the recall presentations with the correct keyboard figure.

Test 5. Memory (Immediate/Delayed) – involves both immediate and short-term memory of symbols under continuously changing storage state. The immediate memory test consists of a continuous random series of presentations of one of the nine geometric keyboard figures. The subject is instructed to depress the appropriate keyboard button for the figure which appeared two figures back when the third figure appears on the display. Each time a new figure appears, the subject is to press the appropriate button for the figure which appeared two back. Each of the nine figures on the keyboard is presented three times, in a quasi-random order, requiring a total of 25 responses. In the immediate memory test (Part 1) the figures are displayed for a two second stimulus duration with a two second intersignal interval. Before the test begins, the subject is given five practice presentations, requiring three responses.

The delayed memory portion of the test (Part 2) has an intersignal interval of five seconds. For both parts, the score (Correct Answers) is the number of correct responses.

Test 6. Concept Identification – requires that the subject identify the common element in a series of geometric figures. Both positive and negative instances of the concept (presence or absence of a right angle, or presence of four or five sides) are displayed an equal number of times. The concept to be used for any particular subject is determined by the computer chosing randomly from among the four concepts available.

The subject is initially informed that some of the figures he will see on the screen are alike in a certain way – that they have some property or feature in common. The subject is instructed to press the right-hand "home" key when the figure on the screen has the certain thing that makes it like the others, and to press the left-hand home key if the figure on the screen does not possess the certain property which makes it like the others. After pressing either button, the subject receives feedback regarding the correctness of his choice in the form of a check mark on the screen for a correct response and an "X" for an incorrect response. An "X" also occurs after five seconds if no response is made by the subject. The presentation of the next figure follows approximately one second after the display of the feedback information. No practice trials are given, and the subject receives 48 trials for score. The measure obtained (Correct Answers) is the number of times the subject correctly identifies the presence or absence of the selected property.

Test 7. Performance Under Divided Attention – involves the performance of two compensatory tracking tasks at the same time. Using the hand-controller located to the right of the response panel, the subject tries to keep a short horizontal line as close to the center of the screen as he can. The line is moved either up or down away from the center by a forcing function. At the same time the subject is required to use the hand-controller to the left of the response panel to track the null point between two tones (Morse "A" and "N"). The null point is moved by a second forcing function so that the subject must make continuous adjustments to stay at the null point.

Practice trials are given on the tasks both singly and together before the four 1-minute trials for score begin. The measures obtained are the summed absolute displacements of the two hand-controllers from the target points for each minute of the test. For the visual tracking task these measurements would be in terms of addressable scope units (approximately .01 inch) and for the audio tracking task the unit of measurement is the digital analog of the hand-controller voltage.

Paper-and-Pencil Reference Measures

Scale Reading – is a test of the subject's ability to read scales, dials and meters. There are a variety of scales with various points indicated on them by numbered arrows. The subject is to estimate the numerical value indicated by each arrow. There are four sample items, and 24 scored items, divided into two separately timed sections.

Letter Sets – has items which contain five groups of letters with four letters in each group. Four of the groups of letters are alike in some way. The subject is to find the rule that makes the four groups alike. The fifth group is different from the others and will not fit the rule. He indicates his knowledge of the rule by selecting the group that does not fit. The subject is given two sample items and 30 scored items, divided into two separately timed sections.

Tool Functions – contains questions about the use of tools. In each of the ten items, a tool is depicted and five statements are given concerning the use or type of the tool. The subject must select the statement that best fits the illustration.

Electrical Information – is a test of the subject's knowledge of electricity and electrical devices. It contains ten items which cover a variety of electrical principles and applications.

Mechanical Principles – contains ten items covering mechanical principles and devices, such as gears and pulleys.

Work Knowledge - is a test of how well the subject understands words. Each of the ten items consists of an underlined word followed by five choices. The subject is to decide which one of the five choices most nearly matches the meaning of the underlined word.

Word Grouping – consists of ten items each containing five words. The subject's task is to select the word that does not belong with the others.

Verbal Analogies – is a test of the subject's ability to determine the relationships between words. In these ten items the subject is given one relationship and part of another. The subject's task is to select from among the five choices the one that best completes a relationship similar to the first one (i.e., **Hoof** is to **cow** as **paw** is to __X__).

Block Counting – is a test of the subject's ability to "see into" a 3-dimensional pile of blocks and determine how many pieces are touched by certain numbered blocks. There are two sample items followed by 80 scored items divided into two separately timed sections.

Point Distance – is a test of the subject's ability to compare small distances quickly. Each problem has a central point surrounded by some lines and circles, among which there is a dot marked "a" and a dot marked "b." The subject is to decide which of the two lettered dots is nearer to the central point. There are two sample items. The test is divided into two separately timed sections with 30 items in each section.

Electrical Maze – is a test of the subject's ability to choose a correct path from among five choices. For each item there is a diagram which consists of a large circle at the top of the picture and five lettered boxes at the bottom. In each box there is a dot marked "S" and a dot marked "F." Lines lead from these points to the other boxes and to the circle, with dots indicating connections between lines. The subject must choose the box which has a connection from the "S" through the circle and back to the "F" in the same box. Only one of the five boxes in each item will meet this condition. There are three examples and sixteen scored items.

Pattern Detail – is a test of the subject's ability to remember patterns which have been made by arranging straight lines in several ways. The subject is given five minutes to study a page containing 15 of these patterns. The subject is then given fifteen items in which he must identify which of five alternatives had been presented on the study page.

Rotated Blocks – presents the subject with a reference block and requires that he decide which of five other blocks is the same as the reference block, were it rotated in 3-dimensional space. There are four sample problems and 10 scored items.

Tools – is a test about tools and how they are used. Each of the ten items has a picture of a tool and four other objects. The subject must decide which of the four objects goes with the pictured tool.

Figure Analogies – is a test of how well the subject can discover logical relationships. The subject is given two figures which have a certain relationship to each other. Then a third figure is given which has the same relationship to one of five alternative figures. The subject's task is to select that figure from the alternatives which bears the same relationship to the single figure that the two original figures bear to each other. There are two sample items and ten scored items.

Hidden Figures – is a test of the subject's ability to see a simple figure in a complex drawing. At the top of each page are five figures, and below these are some numbered drawings. The subject is to determine which lettered figure is contained in each of the numbered drawings.

Answer Sheet Marking – is a test of how fast and how accurately the subject can mark answers. The questions in this test appear as pairs of numbers. Each pair stands for one space on the answer sheet. The first number is the number of the question and the second is the number of the space to blacken for that question. There are two separately timed sections in this test, each containing 75 items.

Table Reading – is a test of the subject's ability to read tables quickly and accurately. The items in this test consist of pairs of numbers which correspond to numbers appearing on the abcissa and ordinate of a large table. The subject's task is to find the entry in the table at the intersection of the row and column designated by the pair of numbers. There are five practice problems and 43 scored items in this test.

Large Tapping – requires that the subject place three pencil dots inside a large number of circles arrayed regularly across the page. The score is the number of circles in which the subject places the three dots during the time limit.

Trace Tapping II – consists of small numbered circles connected by an irregular line. The subject is to place one dot in each circle as quickly as he can, starting with the circle numbered one and proceeding along the irregular line. The score is the number of circles in which the subject places a dot.

Discrimination-Reaction – is a test of speed of reaction to a signal. The signal is an arrangement of a black and white circle within a box. The subject's task is to place a check mark on one of four lines to indicate the relationship of the white circle to the black circle. There are eight practice problems and 100 scored items on the test.

IV. SUBJECT TESTING

A total of 380 subjects was drawn from the 3701 Personnel Processing Squadron, Lackland Air Force Base, Texas, from among personnel awaiting assignment or technical training course openings after completion of basic training. A maximum of sixteen subjects was assigned for testing each day, with half receiving the psychomotor/perceptual battery in the morning while the other half took the paper-and-pencil reference battery. In the afternoon the two groups were switched so that every subject took both the paper-and-pencil and psychomotor/perceptual batteries. The paper-and-pencil battery required approximately four hours for completion, while the psychomotor/perceptual battery took approximately 75 minutes per pair of subjects. Data on 75 subjects were discarded due to incomplete test results leaving 305 subjects for whom complete test data was available on both the paper-and-pencil and psychomotor/perceptual batteries.

V. DATA ANALYSIS

The test results were analyzed to determine the psychometric characteristics of the battery and to compare the performance of "high" and "low" ability subjects (as defined by performance on the Armed Forces Qualification Test).

Reliability estimates for the tests in the battery were determined using the Kuder-Richardson Formula 20 (KR-20), where appropriate, and an odd-even split half procedure, with correction for test length, where the KR-20 was not applicable. These reliability estimates, along with the method of computation, are given in Table 1.

Table 1. **Reliability estimates for Tests Contained in the Psychomotor/Perceptual Battery**
(N = 305)

Test	Reliability
1 – Correct Answers	.93*
1 – Response Time	.83**
2 – Correct Answers	.84*
2 – Perception Time	.86**
2 – Response Time	.94**
3 – Correct Answers	.92*
3 – Perception Time	.88**
3 – Response Time	.93**
4 – Part 1	.64*
4 – Part 2	.19*
5 – Parts 1 + 2	.93*
6 – Correct Answers	.81*
7 – Line Error	.95**
7 – Tone Error	.79**

*Reliability estimates obtained from Kuder-Richardson Formula 20.

**Reliability estimates obtained from correlation of odd and even items and corrected by Flanagan formula (Cronbach, 1951).

Two factor analyses, with varimax rotation, were performed. The first factor analysis was performed on the results of the psychomotor/perceptual battery alone, and the second analysis was performed on the combined paper-and-pencil reference battery and psychomotor/perceptual battery results. The factor analysis of the psychomotor/perceptual battery alone resulted in the identification of seven factors which together accounted for 68% of the variance of the battery. The rotated factors along with the loadings of the variables which defined the factors are given in Table 2. Factor loadings less than .3 are not listed and were not considered in the interpretation of the factors. In both analyses, factor extraction was terminated when the eigenvalue became less than 1.0.

The second factor analysis, which examined the combined batteries, resulted in the identification of eleven factors. The eleven factors accounted for 60% of the variance in the battery, and are listed in Table 3. As in the first analysis, factor loadings of less than .3 were ignored.

Part of the objective of this study was the identification of tests which could be used with disadvantaged or culturally deprived personnel who typically score significantly lower than the majority group members on the conventional armed forces screening instruments. Therefore, an analysis was performed to determine the degree to which these comparatively "high" and "low" ability groups differed in their scores on the psychomotor/perceptual battery. This was achieved by dividing the total sample into three groups with approximately the same number of subjects in each group, based upon their score on the Armed Forces Qualification Test (AFQT). This resulted in a "low" ability group of 97 subjects with scores of less than 54 on the AFQT; a middle group of 104 subjects with scores between 54 and 73; and a "high" ability group of 104 subjects with scores greater than 73.

Means and standard deviations for the "high" and "low" ability groups were obtained and comparisons made for all variables in the psychomotor/perceptual battery. For comparison purposes, the variables from the paper-and-pencil reference battery were also included. The means, standard deviations, and Z-test statistic for each comparison are given in Table 4.

Table 2. **Rotated Factors, Psychomotor/Perceptual Battery**
(N = 305)

Variable	Factor Loading	Variable	Factor Loading
Factor I (Visual Tracking)		**Factor II (Auditory Tracking)**	
Test 7 Performance Under Divided Attention-Line Error Minute 2	.93	Test 7 Performance Under Divided Attention-Tone Error Minute 2	.83
Test 7 Performance Under Divided Attention-Line Error Minute 3	.91	Test 7 Performance Under Divided Attention-Tone Error Minute 3	.82
Test 7 Performance Under Divided Attention-Line Error Minute 1	.89	Test 7 Performance Under Divided Attention-Tone Error Minute 4	.82
Test 7 Performance Under Divided Attention-Line Error Minute 4	.89	Test 7 Performance Under Divided Attention-Tone Error Minute 1	.81
Factor III (Figural Memory)		**Factor IV (Position Memory)**	
Test 5, Memory (Delayed) Part 2	.85	Test 2, Perceptual Speed-Correct Answers	.84
Test 5, Memory (Immediate) Part 1	.83	Test 1, Kinesthetic Memory-Correct Answers	.63
Test 3, Performance Under Stress-Correct Answers	.51		
Test 2, Perceptual Speed-Response Time	−.41	**Factor VI (Motor Speed)**	
Test 1, Kinesthetic Memory-Correct Answers	.36	Test 3, Performance Under Stress-Response Time	.90
Test 2, Perceptual Speed-Perception Time	−.36	Test 2, Perceptual Speed-Response Time	.71
Factor V (Associative Speed)		**Factor VII (Perceptual Speed)**	
Test 4, Associative Learning Part 1	−.69	Test 3, Performance Under Stress-Perception Time	.90
Test 1, Kinesthetic Memory-Response Time	.68	Test 2, Perceptual Speed-Perception Time	.70
Test 4, Associative Learning Part 2	−.54		
Test 6, Concept Identification-Correct Answers	−.45		
Test 2, Perceptual Speed-Perception Time	.32		

Table 3. **Rotated Factors, Combined Psychomotor/Perceptual and Reference Paper-and-Pencil Batteries**
(N = 305)

Variable	Factor Loading	Variable	Factor Loading
Factor I (Verbal)		**Factor II (Spatial Relations)**	
Word Knowledge	−.81	Hidden Figures	.68
Verbal Analogies	−.76	Pattern Detail	.65
Word Grouping	−.73	Figure Analogies	.63
Letter Sets	−.56	Rotated Blocks	.58
Scale Reading	−.55	Electrical Maze	.50
Electrical Information	−.45	Block Counting	.42
Table Reading	−.40	Point Distance	.37
Mechanical Principles	−.40	Letter Sets	.37
Figure Analogies	−.39	Scale Reading	33
Test 6, Concept Identification-Correct Answers	−.35	Mechanical Principles	.31
Block Counting	−.35		
Factor III (Visual Tracking)		**Factor IV (Figural Memory)**	
Test 7, Performance Under Divided Attention-Line Error, Minute 2	.92	Test 5, Memory Part 1 (Immediate)	.74
		Test 5, Memory Part 2 (Delayed)	.71
		Test 1, Kinesthetic Memory-Correct Answers	.56
Test 7, Performance Under Divided Attention-Line Error, Minute 3	.91	Test 3, Performance Under Stress-Correct Answers	.50
		Discrimination-Reaction	.49
Test 7, Performance Under Divided Attention-Line Error, Minute 1	.89	Answer Sheet Marking, Rights	.49
		Table Reading	.49
		Test 2, Perceptual Speed-Response Time	−.46
Test 7, Performance Under Divided Attention-Line Error, Minute 4	.88	Test 2, Perceptual Speed-Correct Answers	.44
		Block Counting	.37
		Point Distance	.36
		Test 2, Perceptual Speed-Perception Time	−.35
		Letter Sets	.31
Factor V (Auditory Tracking)		**Factor VI (Mechanical)**	
Test 7, Performance Under Divided Attention-Tone Error, Minute 2	.81	Tools	−.75
		Tool Functions	−.74
Test 7, Performance Under Divided Attention-Tone Error, Minute 3	.81	Electrical Information	−.62
		Mechanical Principles	−.55
Test 7, Performance Under Divided Attention-Tone Error, Minute 1	.81	Electrical Maze	−.31
Test 7, Performance Under Divided Attention-Tone Error, Minute 4	.79		
Factor VII (Associative Speed)		**Factor VIII (Motor Speed)**	
Test 4, Associative Learning Part 1	−.60	Test 3, Performance Under Stress-Response Time	.85
Test 1, Kinesthetic Memory-Response Time	.55	Test 2, Perceptual Speed-Response Time	.65
Test 4, Associative Learning Part 2	−.48		
Factor IX (Manual Dexterity I)		**Factor X (Manual Dexterity II)**	
Answer Sheet Markings, Wrongs	.86	Large Tapping	−.78
Answer Sheet Markings, Rights	−.39	Trace Tapping II	−.71
Test 2, Perceptual Speed-Correct Answers	−.35	Answer Sheet Marking, Rights	−.42
		Discrimination-Reaction	−.33
		Table Reading	−.33
Factor XI (Perceptual Speed)			
Test 3, Performance Under Divided Attention-Perception Time	.84	Test 2, Perceptual Speed-Perception Time	.72
		Test 6, Concept Identification-Correct Answers	−.33

Table 4. **Comparison of Total, Upper and Lower Groups, on All Measures**

Test	Total (N=305) Mean	Total (N=305) SD	Upper (N=104) Mean	Upper (N=104) SD	Lower (N=107) Mean	Lower (N=107) SD	z
Paper-and-Pencil Reference							
1. Scale Reading	8.95	5.39	12.25	5.44	5.62	3.79	10.07***
2. Letter Sets	15.38	5.39	17.99	4.75	13.22	5.29	6.71***
3. Tool Functions	5.63	2.20	6.18	2.21	4.87	2.05	4.38***
4. Electrical Information	5.24	2.01	5.96	1.89	4.53	1.95	5.29***
5. Mechanical Principles	6.18	2.37	7.29	2.12	5.10	2.17	7.21***
6. Word Knowledge	6.58	2.55	7.97	2.07	4.94	2.38	9.62***
7. Word Grouping	5.89	2.27	7.27	1.93	4.67	2.07	9.18***
8. Verbal Analogies	5.81	2.42	6.92	2.30	4.44	2.14	7.92***
9. Block Counting	24.36	12.28	30.36	11.52	19.55	11.45	6.67***
10. Point Distance	21.72	10.96	25.79	9.76	18.30	11.51	4.96***
11. Electrical Maze	4.68	3.85	6.11	4.05	3.41	3.46	5.08***
12. Pattern Detail	5.59	3.58	6.47	3.49	4.52	3.88	3.75***
13. Rotated Blocks	4.76	2.37	5.90	2.49	3.77	2.18	6.46***
14. Tools	5.93	2.16	6.18	2.12	5.44	2.09	2.48**
15. Figure Analogies	5.74	2.54	7.11	2.20	4.41	2.47	8.14***
16. Hidden Figures	2.89	2.29	3.78	2.45	2.43	2.15	4.14***
17. Answer Sheet Marking (Rights)	90.03	20.98	94.26	20.80	87.05	22.06	2.38**
18. Answer Sheet Marking (Wrongs)	1.55	6.71	1.29	5.67	2.28	9.98	0.86
19. Table Reading	18.21	7.46	21.37	7.04	15.49	7.17	5.85***
20. Large Tapping	74.18	17.64	74.79	17.01	73.01	19.16	0.69
21. Trace Tapping II	107.39	20.37	109.32	18.32	105.30	23.36	1.35
22. Discrimination-Reaction	72.44	120.83	77.19	19.81	69.15	21.59	2.74**
Psychomotor/Perceptual Battery							
23. Test 1 – Correct Answers	12.17	7.24	14.13	6.85	11.42	7.22	2.73**
24. Test 1 – Response Time	253.68	60.33	241.44	59.27	257.41	60.89	1.88
25. Test 2 – Correct Answers	14.40	4.48	15.16	3.66	13.07	5.01	3.36***
26. Test 2 – Perception Time	218.18	74.52	194.73	48.47	229.31	91.93	3.30***
27. Test 2 – Response Time	172.21	43.19	168.21	44.87	173.51	45.11	0.83
28. Test 3 – Correct Answers	6.06	5.78	6.92	6.22	4.98	5.02	2.44**
29. Test 3 – Perception Time	318.88	117.91	304.24	85.44	328.93	116.90	1.69
30. Test 3 – Response Time	220.01	99.39	210.43	51.52	219.12	58.47	1.11
31. Test 4 – Part 1	3.52	2.04	3.98	1.97	3.16	1.99	2.91**
32. Test 4 – Part 2	1.96	1.22	2.09	1.16	1.79	1.19	1.76
33. Test 5 – Part 1	12.77	5.77	14.45	5.81	12.12	6.19	2.74**
34. Test 5 – Part 2	16.06	7.36	18.32	6.52	15.05	7.91	3.18**
35. Test 6 – Correct Answers	28.98	7.16	31.04	7.21	26.80	6.25	4.46***
36. Test 7 – Line Error 1	5967.	2190.	5635.	1723.	6220.	2635.	1.85
37. Test 7 – Line Error 2	5978.	2122.	5678.	1866.	6254.	2526.	1.83
38. Test 7 – Line Error 3	5929.	2056.	5893.	1991.	6056.	2330.	0.53
39. Test 7 – Line Error 4	5819.	2059.	5587.	1938.	6015.	2261.	1.43
40. Test 7 – Tone Error 1	2244.	782.	2083.	702.	2270.	771.	1.79
41. Test 7 – Tone Error 2	2188.	824.	1906.	654.	2297.	804.	3.77***
42. Test 7 – Tone Error 3	2173.	843.	2077.	785.	2109.	721.	0.29
43. Test 7 – Tone Error 4	2138.	827.	1954.	730.	2226.	805.	2.50**

*P < .05.
**P < .01.
***P < .001.

VI. RESULTS AND DISCUSSION

Results of the analyses performed on the tests in the battery indicate that, with only one exception, they are highly reliable measures. The only exception is Test 4 – Associative Learning. The internal consistency of the test of associative learning under the one-half second learning presentation condition (Test 4, Part 2) is so low as to indicate that the subjects were probably operating at the chance level in selecting their responses. Additionally, Part 1 of Test 4 shows rather low reliability, indicating a need to consider possible revisions to that test. These may include alterations to the instructions, revision of the novel figures which are paired with the keyboard figures in the learning trials, or lengthening of the presentation intervals during the learning trials.

Although interpretation is difficult at best, the factor analyses of the psychomotor/perceptual tests, both with and without the context of paper-and-pencil measures, were performed in hopes of roughly determining whether functional interdependencies exist. As the results discussed later indicate, independence of function does exist between some of the psychomotor/perceptual tests and there is little in common between the psychomotor/perceptual tests and the paper-and-pencil counterparts. Demonstration of the merit of the psychomotor/perceptual tests can only come with their validation in a variety of technical schools – a study is now underway.

The factor analysis of the perceptual/psychomotor battery by itself revealed several interesting relations between the tests in the battery. The first two factors obtained (after varimax rotation) were Visual Tracking and Auditory Tracking, both of which are contained wholly in Test 7. These two factors seem to contain almost all of the variance associated with Test 7, as none of the eight variables from this test have loadings above .14 on any of the other factors. Furthermore, these factors are unique to Test 7, with no variable from any of the other tests loading above .2 on these two factors.

The third factor identified seems to be principally associated with some sort of memory process. It has been titled Figural Memory, as it has as its principal defining variables those test in which the subject must remember strings of geometric figures in particular order. This is different from Factor IV, which has been called Position Memory, in that Factor IV has a large component dealing with the positions of the geometric figures or the switches associated with them on the response panel, Factor IV might alternately be called a Kinesthetic Memory factor.

Factor V is the least clear of the factors. There are no variables which load highly on this factor, and there is no obvious connection between the variables which define the factor outside of the fact that they all involve the acquisition of information regarding pairs or series of figures. For want of a better understanding of its nature, the factor has been tentatively named Associative Speed. Factors VI and VII are relatively clear and have been named Motor Speed and Perceptual Speed, respectively.

Factor analysis of the comined correlation matrix of perceptual/psychomotor battery variables and variables from the paper-and-pencil reference battery resulted in the identification of the seven factors already described and an additional four factors which were relatively unique to the paper-and-pencil measures.

As in the case in almost all factor analyses in which either word knowledge or verbal items are used, a Verbal Factor (Factor I) was identified. A Spatial Relations Factor (Factor II), which apparently involves the ability to deal with figures on a fairly abstract level was identified. A Mechanical Factor (Factor VI) was isolated on which those tests that require some knowledge of tools and mechanical principles load heavily. In addition, two factors which seem to relate to manual manipulation were identified. These factors were called Manual Dexterity I (Factor IX) and Manual Dexterity II (Factor X); the distinction between the two apparently lying in the degree of fineness of the actions required.

In almost all the factors identified there was no mixing of variables from the two batteries. That is, the variables from the psychomotor/perceptual battery loaded almost exclusively on the factors associated with that battery and very little on the factors associated with the paper-and-pencil battery. Likewise, the measures from the paper-and-pencil battery loaded primarily on the four factors associated with that bettery and not on the factors from the psychomotor/perceptual/perceptual battery. Thus, it seems evident that there is a large amount of variance in the psychomotor/perceptual battery that is completely unrelated to the paper-and-pencil measures. This is encouraging as it indicates these psychomotor/perceptual tests have the potential for making unique contributions to predictions of success and failure in technical training courses, for whatever it is that these tests are measuring, it is unique to these tests and is not being measured by paper-and-pencil tests.

The only area of substantial overlap between the two batteries is in Factor IV – Figural Memory. While the principal defining variables for this factor come from the psychomotor/perceptual battery, several of the measures from the paper-and-pencil battery are also found to load on this factor, to the extent that approximately 25% of the variance in the Discrimination-Reaction, Answer Sheet Marking, and Table Reading tests is determined by this factor.

In studying the results of the comparisons of mean performance of the "high" and "low" ability groups on the psychomotor/perceptual measures, one notes that while in every instance the "high" ability group performed better than the "low" ability group, these differences were generally of a lesser magnitude than the differences between the two groups on the paper-and-pencil measures. The small differences between mean performance of the groups judged to be "high" and "low" ability on the basis of the traditional selection measure (AFQT) would indicate that these measures are less susceptable to the influences of prior educational experiences and cultural differences which are generally accepted as determining, at least in part, scores on traditional paper-and-pencil measures.

VII. CONCLUSIONS AND RECOMMENDATIONS

The tests contained in the psychomotor/perceptual battery seem to be measuring abilities that are unique to these tests and not measured by paper-and-pencil tests. Additionally, there is a less pronounced difference between the traditionally defined "high" and "low" ability group on the psychomotor/perceptual battery as compared with the paper-and-pencil measures. These two properties of the battery, combined with the fairly high reliability of almost all the measures, suggest that it may prove highly useful in improving the predictions of success in Air Force training schools, especially for those personnel who are normally designated as "low" ability and therefore, high risks in training situations.

It is highly recommended that additional studies of this battery be undertaken to investigate the degree of validity of the tests for prediction of training success and failure. These studies should address both the absolute predictive validity of the test and the incremental validity over and above the present selection instruments. Additionally, it may prove very interesting to determine the differential validity of the tests for traditionally defined "high" and "low" ability individuals.

Studies of these types may add significantly to our understanding of the types and amounts of abilities required for success in Air Force training situations, and may allow the Air Force to achieve savings both in training dollars and in personnel effectiveness through assignment of personnel previously considered marginal risks to training areas where their probability of success is maximized.

REFERENCES

Cronbach, L.J. Coefficient alpha and the internal structure of tests. *Psychometrica*, 1951, **16**, p. 297-334.

McLaurin, W.A. *Validation of a Battery of performance tests for prediction of aerospace ground equipment course grades.* AFHRL-TR-73-20, AD-774 586. Lackland AFB, Tex.: Personnel Research Division, Air Force Human Resources Laboratory, November 1973.

APPENDIX A: SUPPLEMENTARY TECHNICAL DATA

Table A1 presents correlations among each of the variables from both the Psychomotor/Perceptual Battery and the paper-and-pencil measures. Table A2 and A3 summarize the factor loadings from each of the factor analyses. Only factor loadings greater than .30 are included.

Table A1. **Correlations Among Psychomotor/Perceptual and Paper-and-Pencil Measures**
(N = 305)

Test	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Scale Reading		53	24	28	44	44	42	38	45	42	30	27	41	09	40	29	26	–01	48	11	08
Letter Sets			21	21	47	51	46	49	49	35	34	37	37	05	47	28	35	–08	51	17	20
Tool Functions				37	25	25	27	21	33	17	29	24	26	55	24	16	09	–07	23	07	13
Electrical Information					43	36	35	27	26	15	25	11	20	29	16	04	14	–10	26	14	11
Mechanical Principles						39	38	37	50	30	43	34	41	41	39	25	21	–11	35	14	23
Word Knowledge							58	64	40	24	21	18	28	01	40	21	26	–11	42	16	11
Word Grouping								55	40	23	26	17	35	08	43	29	20	–08	37	07	06
Verbal Analogies									36	19	22	26	28	–01	43	22	21	–18	37	10	09
Block Counting										49	41	35	43	25	44	36	43	–04	53	21	25
Point Distance											21	26	32	11	25	23	35	–04	41	17	14
Electrical Maze												34	34	22	40	27	14	–02	28	05	14
Pattern Detail													32	29	39	29	18	–09	23	14	16
Rotated Blocks														24	49	39	11	–08	34	02	07
Tools															15	12	07	–05	11	11	17
Figure Analogies																48	17	–11	37	10	21
Hidden Figures																	15	–11	29	08	22
Ans. Sheet Marking (Rights)																		–32	59	26	29
Ans. Sheet Marking (Wrongs)																			–09	04	–01
Table Reading																				22	30
Large Tapping																					41
Trace Tapping II																					
Discrimination-Reaction																					
Test 1 – Correct Answers																					
Test 1 – Response Time																					
Test 2 – Correct Answers																					
Test 2 – Percep. Time																					
Test 2 – Response Time																					
Test 3 – Correct Answers																					
Test 3 – Perception Time																					
Test 3 – Response Time																					
Test 4 – Part 1																					
Test 4 – Part 2																					
Test 5 – Part 1																					
Test 5 – Part 2																					
Test 6 – Correct Answers																					
Test 7 – Line Error 1																					
Test 7 – Line Error 2																					
Test 7 – Line Error 3																					
Test 7 – Line Error 4																					
Test 7 – Tone Error 1																					
Test 7 – Tone Error 2																					
Test 7 – Tone Error 3																					
Test 7 – Tone Error 4																					

Note. – Decimel points omitted.

Table A1 *(Continued)*

22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
29	22	−15	15	−18	−21	18	−10	−05	19	13	24	31	23	−05	−04	−06	−02	−17	−25	−13	−16
35	36	−17	13	−28	−28	24	−16	−12	27	21	33	36	21	−13	−08	−10	−08	−23	−26	−16	−21
15	21	−11	15	−12	−12	05	03	−05	13	14	06	07	09	−11	−08	−05	−04	−19	−25	−19	−31
14	22	−17	16	−17	−10	12	−08	−04	14	−01	06	04	19	−06	−08	−03	−05	−15	−14	−07	−17
25	29	−19	05	−23	−19	17	−10	−11	25	17	22	21	26	−14	−06	−06	−03	−27	−30	−24	−26
25	20	−12	13	−24	−08	15	−11	02	25	20	18	18	24	−06	−03	−07	−08	−24	−22	−09	−16
24	18	−14	10	−22	−11	09	−08	04	25	20	19	23	21	−07	−04	−04	−08	−14	−20	−09	−11
23	14	−16	05	−22	−02	13	−12	04	29	18	22	15	19	−08	−04	−06	−04	−14	−19	−07	−12
33	40	−27	13	−26	−32	25	−14	−14	25	24	34	37	28	−06	−06	−08	−04	−26	−36	−30	−29
27	32	−17	12	−26	−21	16	−15	−06	17	15	25	23	12	−10	−07	−05	−10	−09	−21	−16	−15
17	21	−20	05	−16	−17	13	−12	−11	27	16	22	19	19	−08	−11	−08	−10	−06	−12	−10	−21
16	21	−10	07	−18	−12	08	−12	−06	30	14	16	15	13	00	00	04	01	−02	−15	−11	−14
25	27	−16	20	−14	−19	13	−04	−08	23	07	23	21	20	03	03	03	05	−13	−24	−16	−21
09	19	−09	08	−05	−18	08	−00	−14	11	07	09	04	05	−02	−01	00	02	−12	−19	−16	−20
31	30	−20	09	−23	−13	17	−14	−08	33	17	23	25	20	−07	−01	−06	−05	−19	−25	−16	−22
15	28	−16	03	−03	−10	09	−04	−08	18	14	20	19	02	−01	00	−01	−06	−14	−23	−14	−24
37	29	−22	20	−32	−28	26	−18	−13	16	21	38	36	12	−10	−12	−15	−15	−20	−24	−20	−20
02	−07	−03	−16	03	−02	−08	05	−02	−04	−02	−03	−04	−03	−07	−06	−06	−08	10	05	09	08
47	35	−22	18	−32	−30	27	−19	−15	19	22	43	36	19	−11	−09	−12	−13	−19	−29	−23	−21
23	12	−14	01	−01	−19	17	−03	−10	14	09	05	12	13	−05	−04	00	−12	−10	−07	−11	−01
22	17	−19	02	−06	−21	11	−07	−17	07	17	13	14	05	−06	−08	−04	−10	−14	−22	−17	−11
	37	−20	12	−23	−20	18	−14	−08	13	16	35	35	08	−09	−04	−08	−13	−14	−16	−18	−12
		−13	31	−24	−27	28	−09	−15	18	13	36	29	13	06	00	04	01	−19	−26	−19	−23
			−05	30	36	−17	13	10	−28	−20	−24	−20	−10	13	09	08	15	16	17	13	14
				−14	−06	13	−03	−01	08	07	16	12	05	00	−03	03	−02	−10	−05	−09	−08
					04	−30	63	02	−30	−21	−32	−29	−18	14	11	13	05	09	20	13	14
						−27	00	47	−08	−08	−32	−37	−01	06	08	08	14	12	14	09	07
							−19	−13	14	15	32	33	11	−04	−06	−06	−05	−10	−10	−06	−04
								39	−22	−22	−16	−19	−14	06	−02	05	−03	02	10	10	04
									−09	−13	−17	−14	−04	−02	−02	−01	01	08	07	13	06
										27	18	21	17	−11	−08	−14	−13	−15	−19	−11	−10
											20	13	08	−09	−04	−04	−06	−11	−13	−15	−11
												68	09	−06	−07	−07	−07	−15	−18	−18	−13
													05	−08	−08	−10	−13	−23	−23	−18	−12
														03	06	02	06	−08	−12	−07	−15
															80	75	71	15	09	07	16
																80	77	06	03	02	08
																	76	13	03	02	07
																		04	−02	−05	06
																			64	57	54
																				58	61
																					59

Table A2. **Factor Loadings, Psychomotor/Perceptual Battery**
(N = 305)

Test	Factor						
	I	II	III	IV	V	VI	VII
1 – Correct Answers			.36	.63			
1 – Response Time					.68		
2 – Correct Answers				.84			
2 – Perception Time			−.36		.32		.70
2 – Response Time			−.41			.71	
3 – Correct Answers			.51				
3 – Perception Time							.90
3 – Response Time						.90	
4 – Part 1					−.69		
4 – Part 2					−.54		
5 – Part 1			.83				
5 – Part 2			.85				
6 – Correct Answers							
7 – Line Error 1	.89						
7 – Line Error 2	.93						
7 – Line Error 3	.91						
7 – Line Error 4	.89						
7 – Tone Error 1		.81					
7 – Tone Error 2		.83					
7 – Tone Error 3		.82					
7 – Tone Error 4		.82					

Table A3. **Factor Loadings, Combined Psychomotor/Perceptual and Reference Paper-and-Pencil Batteries**
(N = 305)

Test	Factors										
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
Scale Reading	−.55	.33									
Letter Sets	−.56	.37		.31							
Tool Functions						−.74					
Electrical Information	−.45					−.62					
Mechanical Principles	−.40					−.55					
Word Knowledge	−.81										
Word Grouping	−.73										
Verbal Analogies	−.76										
Block Counting	−.35	.42		.37							
Point Distance		.37		.36							
Electrical Maze		.50				−.31					
Pattern Detail		.65									
Rotated Blocks		.58									
Tools						−.75					
Figure Analogies	−.39	.63									
Hidden Figures		.68									
Ans. Sheet Marking (Rights)				.49					−.39	−.42	
Ans. Sheet Marking (Wrongs)									.86		
Table Reading	−.40			.49						−.33	
Large Tapping										−.78	
Trace Tapping II										−.71	
Discrimination-Reaction				.49						−.33	
Test 1 – Correct Answers				.56							
Test 1 – Response Time							.55				
Test 2 – Correct Answers				.44					−.35		
Test 2 – Perception Time				−.35							.72
Test 2 – Response Time				−.46				.65			
Test 3 – Correct Answers				.50							
Test 3 – Perception Time											.84
Test 3 – Response Time								.85			
Test 4 – Part 1							−.60				
Test 4 – Part 2							−.48				
Test 5 – Part 1				.74							
Test 5 – Part 2				.71							
Test 6 – Correct Answers	−.35										−.33
Test 7 – Line Error 1			.89								
Test 7 – Line Error 2			.92								
Test 7 – Line Error 3			.91								
Test 7 – Line Error 4			.88								
Test 7 – Tone Error 1					.81						
Test 7 – Tone Error 2					.81						
Test 7 – Tone Error 3					.81						
Test 7 – Tone Error 4					.79						

I. Introduction

The recorded Perceptual/Psychomotor Battery instruction to the subjects are given in the first part of this appendix. The material which is actually on the audio tape is indented and blocked. Statements in all capital letters appear as teletype messages to the operator. Actions required by the operator are placed in brackets, while parentheses enclose statements of what the computer program is doing. The "#" symbol indicates the position in the text of cue tones, which appear on the instruction tape to provide synchronizing information to the computer.

The second part of this appendix contains a complete listing of the stimuli used in Test 1 through Test 6, in the order in which they are given to the subjects.

II. Instructions to Subjects

READY TO START

(Press S and CR)[1]

Welcome to the Personnel Division of the Air Force Human Resources Laboratory. You have been selected to help in the development of some new tests. These tests may become part of the battery of tests used in selection in the future.

Your performance on the test will **not** be used to evaluate you. It will be used to evaluate the tests so do your best.

First, let's check the things you will use during the tests. Look at the TV-like screen in "#" front of you.

(Present Figure T2 on screen)[2]

The screen is used in all tests. The picture on the screen is like many which you will see during the test "#."

(Backlight red buttons)[3]

Now look at the central panel in front of you. The lights in the red buttons near the front of the panel, one on the left and one on the right, have just come on. During some of the tests, you will use these red buttons. You will use your thumbs to keep these red buttons "#" pressed down.

(Backlight toggle switches and red buttons)

Now, note the lights which have just come on below the row of four toggle switches toward the rear of the panel. These switches work up and down. You will use them both "#" ways during the tests.

(Remove T2 from screen)

Let's try a practice trial. A picture will appear on the screen. Then you will hear "#" this bell.

(Ring bell)

That bell is the signal to let go of one of the red buttons and pull down the toggle switch which has the same picture under it, then put your thumbs back on the red buttons and press them down. You must keep them pressed down except when you are pulling the toggle switch. When you are ready to pull the toggle switch, lift **one** hand off a red button, move as fast ~~as~~you can, pull the correct switch and return your thumb to press down the red button again. You can use either hand to pull the toggle switch – keep the other red button pressed down.

---

[1] **Note.** — S and CR refer to the "S" and "Carriage Return" keys on the teletype.

[2] **Note.** — Illustrations of the geometric figures are given in Figures A1–A3.

[3] **Note.** — The red buttons on the "home keys" in the lower right and left corners of the response panel.

Now, look for the picture on the screen and when you hear the bell, let go of one red button and pull the toggle switch with the same picture. Remember to get right back on the red buttons "#."

(Stop audio)

(Wait until all subjects on both red buttons (RB))

(Present T2 on screen)

(Ring bell)

(When RB released, erase screen)

(Wait until subjects complete task or 7 seconds. Warn operator if a subject fails task.)

Notice that the picture disappeared from the screen when you took your thumb off the red button. Make sure you have pressed down on both red buttons after you pull "#" the toggle switch.

(Turn off lights)

There is a keyboard in the center of the panel and a joy-stick to the left and right of the panel. You will get instructions about these later when it is time to use them. Each test will only take a "#" few minutes.

TEST 1. KINESTHETIC LEARNING

READY FOR TEST 1

(Press S and CR)

(Backlight toggle switches)

The lights under the toggle switches are now on. Notice that each switch has a different picture with it. In this test, all four pictures will appear on the screen. Your job will be to pull the switches down in the same order that you see them on the screen. They will always be in the same "#" order.

(Backlight red buttons)

Except when pulling the four switches, your thumbs should be on the red buttons. When you are ready to pull the switches, do so using **one** hand. When you take your thumb off a red button, the pictures on the screen will disappear. You must remember the order of the pictures while you pull the toggle switches down. You should work as fast as you can, but be sure you hear the click when you pull the toggle switches all the way down. After the pictures appear on the screen, you will hear the bell. Do not release a red button until you hear "#" the bell.

READY FOR PRACTICE TRIALS

(Station 1, any questions? Station 2, any question?)

(Press S and CR)

OK, hands on red buttons for practice "#" trials.

(Random choice of sequence 1 (T1 T2 T3 T4) or 2 (T4 T3 T2 T1) Twelve trials of sequence 1 or 2, up to 15 seconds display/response time)

Now, put on the goggles you will find on the desk in front of you. Make sure you can't see anything. If you are wearing eyeglasses, please take them off.

READY FOR BLIND TRIALS

(Press S and CR)

Now, every time you hear the bell, pull the switches in the same order as you did in the practice trials. Thumbs on red buttons, and here "#" we go.

(Turn off backlighting after both S's have depressed red buttons)

Trials 13 through 24, no visual display)

That's the end of this test, please remove the "#" goggles.

PUNCH ON. PRESS CONTINUE

(Turn punch on. Press "CONT")[4]

(Record date, subject(s) identification)

(Record pattern used. Record responses all trials, correct or incorrect.* Record response time (red release to red recovery) trials 1 through 24)

(Failure to complete a trial in 15 seconds results in a response time of zero)

(At end of punch, wait for operator to turn punch off and press S and CR)

(Turn punch off. Press S and CR)

TEST 2. PERCEPTUAL SPEED

READY FOR TEST 2 (A/N OFF)[5]

(Turn the bell tone generator (A/N) off)

(Press S and CR)

In the next test, the pictures on the screen will be shown in "#" different orders.

(Backlight toggle switches)

Your job will be to pull the switches down in the order in which you see the pictures on the screen. "#"

(Backlight red buttons)

Except when you are pulling the switches, keep your thumbs on the red buttons. The first two trials will not count for score. Put your thumbs on the red buttons. When you are ready to pull the switches in the order shown on the screen, do so using one hand. When you take your hand off the red button, the pictures on the screen will disappear. Pull the switches down and return your thumb to the red button as fast as you can. You will NOT hear the bell this time. Okay, thumbs "#" on red buttons.

(Practice trials A and B with 12 seconds display/response time and a 3 second intertrial interval)

RPT OR GO

(Press R to repeat practice trials. Press G to continue.)

READY FOR TRIALS

(Station 1, any questions? Station 2, any questions?)

(Press S and CR)

---

[4] **Note.** — "CONT" refers to the continue switch on the computer console.

*Actual response is not recorded; 1 is recorded for correct responses; 0 is recorded for incorrect responses.

[5] **Note.** — The bell tone and Morse "A" and Morse "N" audio stimuli generator is disabled by a pair of switches on the operator's console.

Now we'll have 20 trials for score. Hands on red buttons; keep them there except when you are "#" pulling switches.

(Trials 1 through 20 with 7 seconds display/response time and a 5 second intertrial interval. Type number correct after each half of test)[6]

(Turn off backlighting)

That is the end of this test. Put your hands "#" in your lap.

PUNCH ON. PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record response, correct or incorrect for all 20 trials. Record perception time (onset of display to release of red button) for all 20 trials. Record motor time (from release to subsequent depression of red button) for all 20 trials)

(Turn punch off. Press S and CR)

TEST 3. PERFORMANCE UNDER STRESS

READY FOR TEST 3

(Press S and CR)

(Backlight toggle switches)

This test is like the last one, except that some of the pictures on the screen will be **shaded**. When the pictures are **unshaded** like they were before, pull the switch down. If the picture is shaded, push the switch up. Picture clear, pull down. Picture shaded, "#" push up.

(Backlight red buttons)

Let's practice. Thumbs on red "#" buttons.

(Practice trials A and B with 12 seconds display/response time and a 3 second intertrial interval)

(If both trials are performed incorrectly, warn operator with message: "A" or "B" NO GOOD)

REPEAT OR GO

(Press R to repeat practice trials. Press G to continue.)

Now we'll have 20 trials for score. During the trials, you will hear things through the earphones. Try to ignore what you hear. What you hear during the trials is not important for the test. Thumbs on red buttons. Remember, clear, pull down. Shaded, "#" push up.

LOAD DISTRACTION. TAPE 2. S/CR.

(Switch audio controls to Channel 2 (Distractor Channel)

(Press S and CR)

(Trials with 12 seconds display/response time and a 3 second intertrial interval)

(Type number correct responses after each half of test)

TAPE 1. LOAD INSTR. S/CR

(Load audio tape containing instructions for Tests 4, 5, 6, 7, of battery)

---

[6] **Note.** — Stimuli used in this and succeeding tests are depicted in Figures A1–A3.

(Switch audio controls for Channel 1 (Instruction Channel))

(Press S and CR)

(Turn off backlighting)

That's the end of this test. Put your hands "#" in your lap.

PUNCH ON. PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record responses; correct or incorrect, for all 20 trials. Record perception times and motor times for all 20 trials)

(Turn punch off. Press S and CR)

TEST 4. ASSOCIATIVE LEARNING

READY FOR TEST 4

(Press S and CR)

Look at the keyboard "#" in front of you.

(Backlight keyboard)

Each button in the keyboard has a different picture. Now, we will draw one of these pictures on the screen. As soon as it appears, press the keyboard button which has the same "#" picture.

(Draw KB-4 on screen)

(When subject presses correct button, erase screen)

Notice that the picture disappeared from the screen when you pressed the keyboard button. During this test, some of these keyboard pictures will show on the screen. With each of these pictures, you will also see a picture that is **not** on the keyboard. Two pictures will appear on the screen, one that is on the keyboard, and one that is not on the keyboard. Each pair of pictures will appear three times during this test. Your job is to learn the pairs. After you have had a chance to learn the pairs, you will see only one of the picutes on the screen. You will have to remember which keyboard picture "#" was paired with it.

READY FOR LEARNING TRIALS

(Station 1, any questions? Station 2, any questions?)

(Press S and CR)

Look at the screen and keep your hands "#" in your lap.

(24 pairs at 2 second stimulus duration and 1 second intersignal interval)

Now you will see only one picture on the screen. Press the keyboard button picture that was with the picture on the screen. You are only allowed a few seconds, so be as fast "#" as you can.

(Test trials with a stimulus duration of 4 seconds and an intersignal interval of 3 seconds)

(Type number of correct responses)

Please place your hands in your lap again. Now you will see two pictures on the screen. One that is on the keyboard, one that is not on the keyboard. Each pair of pictures will appear three times during this test. You will see each pair for a very short time. Your job is to learn these new pairs. Watch the screen. Keep your hands "#" in your lap.

(24 pairs below at 1/2 second stimulus duration and 1/2 second intersignal interval)

Now you will see only one picture on the screen. Press the button picture that was with the picture "#" on the screen.

(Present test trials with a stimulus duration of 4 seconds and an intersignal interval of 3 seconds)

(Type number of correct responses)

(Turn off backlighting)

That's the end of this test. Put your hands "#" in your lap.

PUNCH ON. PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record responses, correct or incorrect, for trials 1 through 16)

(Turn off punch. Press S and CR)

TEST 5. MEMORY, IMMEDIATE AND DELAYED

READY FOR TEST 5.

(Press S and CR)

(Backlight keyboard)

In the next test you will see the keyboard pictures on the screen, one at a time. This is a memory test. Remember the first two pictures. When you see the third picture, press the button for the first picture – when the fourth picture shows, press the button for the second picture. Then continue that way, always pressing the button for the picture which you "#" saw two pictures back.

(Backlight red buttons)

You must keep the red buttons pressed down except when you are pushing a keyboard switch.

Let's practice. Wait until you see the third picture. As soon as you see the third picture, let go of one red button and press the keyboard button for the **first** picture you saw. Then continue, always pressing the button for the picture you saw two pictures back. Thumbs on the red buttons now, here "#" we go.

(Trials A through F with a 2 second stimulus duration, 2 second intersignal interval)

(If either subject presses a button before picture 3, alert operator with "A" or "B" NO GOOD MESSAGE)

(Type number of correct responses for each subject)

REPEAT TO GO

(Press R to repeat practice trials, G to continue)

(Delay 15 seconds before repeating practice to give operator time to demonstrate)

(If a subject does not have both red buttons pressed when stimulus presented, ring teletype bell. Otherwise ignore red buttons)

READY FOR MEMORY TRIALS

(Station 1, any questions? Station 2, any questions?)

(Press S and CR)

OK, now we will begin the test. Remember, when you see the third picture, press the button for the first picture you saw. Then continue, always pressing the button for the picture which you saw two pictures back. OK, thumbs on the red buttons now. Here "#" we go.

(Trials 1 through 27. 2 second stimulus duration, 2 second intersignal interval)

(Type number correct for each subject)

For the rest of this test, everything will be the same except that the time between pictures will be longer. Again, when the third picture shows, press the button for the first picture. Then continue, always pressing the button for the picture which you saw two back. Thumbs on the red buttons now, here "#" we go.

(Trials 28 through 54 with a 2 second stimulus duration and a 5 second intersignal interval)

(Type number correct for each subject)

(Turn off backlighting)

That's the end of this test. Put your hands "#" in your lap.

PUNCH ON. PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record responses, correct or incorrect, for trials 1 through 54)

(Turn punch off. Press S and CR)

TEST 6. CONCEPT IDENTIFICATION

READY FOR TEST 6

(Press S and CR)

In this test, you will use the red buttons again, but in a different way. "#"

For this test,

(Light Right Red Button (RRB))

the red button on the right means yes. "#"

(Light Left Red Button (LRB))

The red button on the left means no. "#"

(Light off)

You will see pictures on the screen, one at a time. Some of these pictures are alike in a certain way. At the beginning, you will have to **guess** how they are alike. "#"

(Light RRB)

Press the yes button on the right when you think the pictures have that certain thing which makes them alike. "#"

(Light LRB)

Press the no button on the left for a picture without the certain thing. "#"

(Light RRB)

Right for yes. "#"

(Light LRB)

Left for No. "#"

(Lights off)

If your guess is correct, you will see "#" a check mark

(Draw check mark on screen)

on the screen. If you are wrong, "#" an

(Draw X on screen)

X will appear. "#" When you see

(erase screen)

a picture, if you guess that it **has** that certain "#" thing,

(Light RRB, draw check)

press the red button on the right. "#" If it does not

(Light LRB, draw X)

have the certain thing, press the red button on the left. "#"

(Erase, lights off)

READY FOR CONCEPT TRIALS

(Station 1, any questions? Station 2, any questions?)

(Press S and CR)

(Light both red buttons)

OK. Now, decide if these figures have the secret thing we are looking for. Here "#" we go.

(Present trials 1 through 48 with up to 5 seconds display/response time and a 2 second display/feedback time. Feedback as appropriate but score as incorrect any response made after the 5 second display/response time. Wait a maximum of an additional 5 seconds for response, if no response, display X and continue)

(Each subject proceeds at his own speed. When one subject finishes, display "WAIT" on his screen until both are done)

(Erase screens)

(Type number correct, each subject)

(Turn off backlighting)

That's the end of this test. Put your hands "#" in your lap.

PUNCH ON, PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record pattern used. Record responses, correct or incorrect, for all trials)

(Correct answer concept will be randomly selected from the following for each pair of subjects:)

1. Figure includes a right angle
2. Figure has no right angle
3. Figure has four sides
4. Figure has five sides

TEST 7. PERFORMANCE UNDER DIVIDED ATTENTION

READY FOR TEST 7

(Press S and CR)

(Display line of dots)

This is a test of how well you can pay attention to two things going on at once. Look at the screen in front of you. There is a line of dots across the center of the screen. "#"

(Display short line)

There are two joysticks in front of you. The joystick on the right controls the movement of the short line on the screeen. The short line will move away from the dotted line. Part of your job is to keep the short line on the dotted line. If the short line moves up, you can bring it down by pulling the joystick toward you. If the short line moves down, push the stick away from you.

Take hold of the joystick and try to keep the short line right on the "#" dotted line.

(Start moving short line)

(30 seconds practice. Then blank screen)

While you are moving the short line on the screen, you will hear dots and dashes over the earphones. You can control these with the left joystick. Part of your job is to move the left joystick away from you or toward you so that the dots and dashes blend into a soft steady sound. If the dot comes before the dash, push the stick away from you. If the dash comes before the dot, pull the stick toward you. If you are right on, you will hear "#" this.

(5 seconds of merged dots and dashes at standard intensity)

The farther you get the left joystick away from the tone, the louder the sound will beome. You will have to keep the joystick moving slowly in the correct direction to keep the soft tone.

Take hold of the joystick on the left and try to keep a soft steady sound like you just heard. Ignore the screen for now. Just work on controlling the "#" sounds.

(30 seconds practice with varying dit and dah intensity)

Take hold of both joysticks now and watch the screen. Keep the short line right on the dotted line and keep the sound soft and steady. "#"

(60 seconds practice, then blank screen and discontinue sound for 2 seconds)

Rest your hands in your lap. You will have four one-minute trials. At the end of each trial, the screen will go blank and the sound will stop. Rest your hands in your lap "#" between trials.

READY FOR ATTENTION TEST

(Station 1, any questions? Station 2, any questions? Hands on joysticks. Go!)

(Press S and CR)

(Short line moving slowly above/below horizontal line of dots for 60 seconds. Simultaneously, varying tone to earphones for 60 seconds)

(Blank screen and discontinue sound)

OK, rest for awhile, then we will "#" begin again.

(Type absolute displacement, each 15 seconds, each hand)

OK, hands on the joysticks again. Here we go. "#"

(Second 60 second trial)

OK, rest for awhile, then we will "#" begin again.

(Type scores as above)

OK, hands on the joysticks again. Here we go. "#"

(Third 60 second trial)

OK, rest for awhile, then we will "#" begin again.

(Type scores)

OK, hands on the joysticks again. Here we go. "#"

(Fourth 60 second trial)

That was the last test. Thank you for your cooperation.

(No cue tone. Allow tape to reset)

(Type scores, 4th minute)

PUNCH ON. PRESS CONTINUE

(Turn on punch. Press "CONT")

(Record scores for each hand separately, for each 15 second subtest. 16 scores for each hand consist of the absolute displacement from the target at the end of each second, summed over 15 seconds)

(Dismiss subjects)

(Punch off. Press S and CR)

END OF BATTERY

III. Test Stimuli

Tables A1 through A4 specify the order in which the various geometric figures were presented to the subjects during Tests 1-6. References in each of the tables direct the reader to the Figure in which the geometric figures corresponding to the alphanumeric designators are located.

Table A4. **Stimuli Presentation Order for Test 1**

Learning Trials 1 – 12	Figure Sequence[1]			
	T1	T2	T3	T4
		or		
	T4	T3	T2	T1

[1] **Note.** – Illustrations of the geometric figures corresponding to T1-T4 are given in Figure A1.

Table A5. **Stimuli Presentation Order for Test 2[1]**

Trial	Figure Sequence			
Practice A	T4	T2	T3	T1
Practice B	T2	T3	T1	T4
1	T4	T1	T3	T2
2	T1	T2	T4	T3
3	T4	T2	T3	T1
4	T4	T3	T1	T2
5	T2	T3	T1	T4
6	T2	T1	T4	T3
7	T3	T1	T2	T4
8	T2	T1	T4	T3
9	T3	T1	T4	T2
10	T4	T2	T1	T3
11	T3	T4	T2	T1
12	T1	T4	T2	T3
13	T4	T1	T3	T2
14	T4	T3	T2	T1
15	T2	T3	T4	T1
16	T1	T4	T2	T3
17	T1	T4	T2	T3
18	T4	T3	T2	T1
19	T3	T1	T2	T4
20	T2	T1	T4	T3

[1] **Note:** — Illustrations of the geometric figures corresponding to T1-T4 are given in Figure A1.

Table A6. **Stimuli Presentation Order for Test 3[1]**

Trial	Figure Sequence			
Practice A	T3	T2S	T1	T4S
Practice B	T2S	T4	T3S	T1S
1	T4S	T1	T3S	T2S
2	T1	T2	T4	T3
3	T4	T2	T3	T1
4	T4S	T3	T1	Ts
5	T2	T3	T1	T4
6	T2S	T1	T4S	T3S
7	T3	T1	T2S	T4S
8	T2	T1	T4	T3S
9	T3	T1	T4	T2
10	T4S	T2	T1S	T3S
11	T3S	T4S	T2S	T1S
12	T1S	T4S	T2S	T3S
13	T4	T1S	T3S	T2S
14	T4S	T3	T2S	T1
15	T2	T3	T4S	T1S
16	T1	T4S	T2	T3
17	T1S	T4S	T2S	T3S
18	T4S	T3S	T2S	T1S
19	T3	T1S	T2	T4
20	T2S	T1	T4	T3S

[1] **Note.** — Illustrations of the geometric figures corresponding to T1-T4 are given in Figure A1.

FIGURE	FIGURE NUMBER
	T1
	T2
	T3
	T4
	T1S
	T2S
	T3S
	T4S

Figure A1. **Toggle switch geometric figures.**

Table A7. **Stimuli Presentation Order for Test 4, Part 1[1]**

Learning Trial	New Figure	Keyborad Figure
1	N–1	KB–6
2	N–2	KB–7
3	N–3	KB–8
4	N–4	KB–1
5	N–5	KB–5
6	N–6	KB–2
7	N–7	KB–3
8	N–8	KB–4
9	N–5	KB–5
10	N–8	KB–4
11	N–3	KB–8
12	N–4	KB–1
13	N–1	KB–6
14	N–2	KB–7
15	N–6	KB–2
16	N–7	KB–3
17	N–3	KB–8
18	N–8	KB–4
19	N–5	KB–5
20	N–2	KB–7
21	N–4	KB–1
22	N–6	KB–2
23	N–7	KB–3
24	N–1	KB–6
Recall Trial		
1	N–1	
2	N–4	
3	N–5	
4	N–2	
5	N–7	
6	N–3	
7	N–6	
8	N–8	

[1] **Note.** — Illustrations of the geometric figures corresponding to N-1 – N-8 and KB-1 – KB-8 are given in Figure A2.

Table A8. **Stimuli Presentation Order for Test 4, Part 2[1]**

Learning Trial	New Figure	Keyboard Figure
1	N–9	KB–8
2	N–10	KB–6
3	N–11	KB–5
4	N–12	KB–1
5	N–13	KB–7
6	N–14	KB–4
7	N–15	KB–2
8	N–16	KB–3
9	N–11	KB–5
10	N–13	KB–7
11	N–16	KB–3
12	N–14	KB–4
13	N–10	KB–6
14	N–12	KB–1
15	N–15	KB–2
16	N–9	KB–8
17	N–10	KB–6
18	N–9	KB–8
19	N–15	KB–2
20	N–12	KB–1
21	N–14	KB–4
22	N–16	KB–3
23	N–11	KB–5
24	N–13	KB–7
Recall Trial		
1	N–14	
2	N–13	
3	N–16	
4	N–12	
5	N–11	
6	N–10	
7	N–15	
8	N–9	

[1] **Note.** — Illustrations are of the geometric figures corresponding to N-1 – N-8 and KB-1 – KB-8 are given in Figure A2.

Table A9. **Stimuli Presentation Order for Test 5, Part 1[1]**

Trial	Keyboard Figure
Practice A	KB–4
Practice B	KB–2
Practice C	KB–7
Practice D	KB–6
Practice E	KB–5
Practice F	KB–3
1	KB–2
2	KB–1
3	KB–7
4	KB–3
5	KB–4
6	KB–6
7	KB–9
8	KB–5
9	KB–8
10	KB–6
11	KB–2
12	KB–3
13	KB–8
14	KB–9
15	KB–1
16	KB–4
17	KB–5
18	KB–7
19	KB–9
20	KB–8
21	KB–1
22	KB–3
23	KB–5
24	KB–6
25	KB–7
26	KB–2
27	KB–4

[1] **Note.** — Illustration of the keyboard figures corresponding to KB-1 – KB-9 are given in Figure A2.

Table A10. **Stimuli Presentation Order for Test 5, Part 2[1]**

Trial	Keyboard Figure
1	KB–5
2	KB–4
3	KB–9
4	KB–6
5	KB–7
6	KB–8
7	KB–3
8	KB–2
9	KB–1
10	KB–5
11	KB–1
12	KB–6
13	KB–7
14	KB–4
15	KB–2
16	KB–3
17	KB–9
18	KB–8
19	KB–7
20	KB–2
21	KB–8
22	KB–1
23	KB–6
24	KB–9
25	KB–4
26	KB–3
27	KB–5

[1] **Note.** — Illustration of the keyboard figures corresponding to KB-1 – KB-9 are given in Figure A2.

KEYBOARD FIGURES

FIGURE	FIGURE NUMBER
	KB-1
	KB-2
	KB-3
	KB-4
	KB-5
	KB-6
	KB-7
	KB-8
	KB-9

NOVEL FIGURES

	N-1		N-9
	N-2		N-10
	N-3		N-11
	N-4		N-12
	N-5		N-13
	N-6		N-14
	N-7		N-15
	N-8		N-16

Figure A2. **Keyboard geometric figures and novel figures.**

Table A11. **Stimuli Presentation Order for Test 6[1]**

Trial	Figure Number	Type[2]	Trial	Figure Number	Type
1	15	4R	25	6	5R
2	3	5R	26	12	4N
3	10	4N	27	15	4R
4	13	4N	28	1	5R
5	19	5N	29	7	4N
6	2	5R	30	0	4N
7	18	4R	31	16	4R
8	6	5R	32	13	4R
9	8	4N	33	8	5R
10	17	4R	34	8	4N
11	11	4N	35	14	4R
12	12	4N	36	24	5N
13	14	4R	37	20	5N
14	5	5R	38	10	4N
15	22	5N	39	17	4R
16	4	5R	40	4	5R
17	24	5N	41	19	5N
18	7	4N	42	22	5N
19	21	5N	43	5	5R
20	16	4R	44	21	5N
21	1	5R	45	3	5R
22	23	5N	46	18	4R
23	9	4N	47	23	5N
24	20	5N	48	11	4N

[1] **Note.** — Illustration of the geometric figures corresponding to the figure numbers are given in Figure A3.

[2] **Note.** — "Type" specifies the number of sides in the figure (4 or 5) and the presence (R) or absence (N) of a right angle.

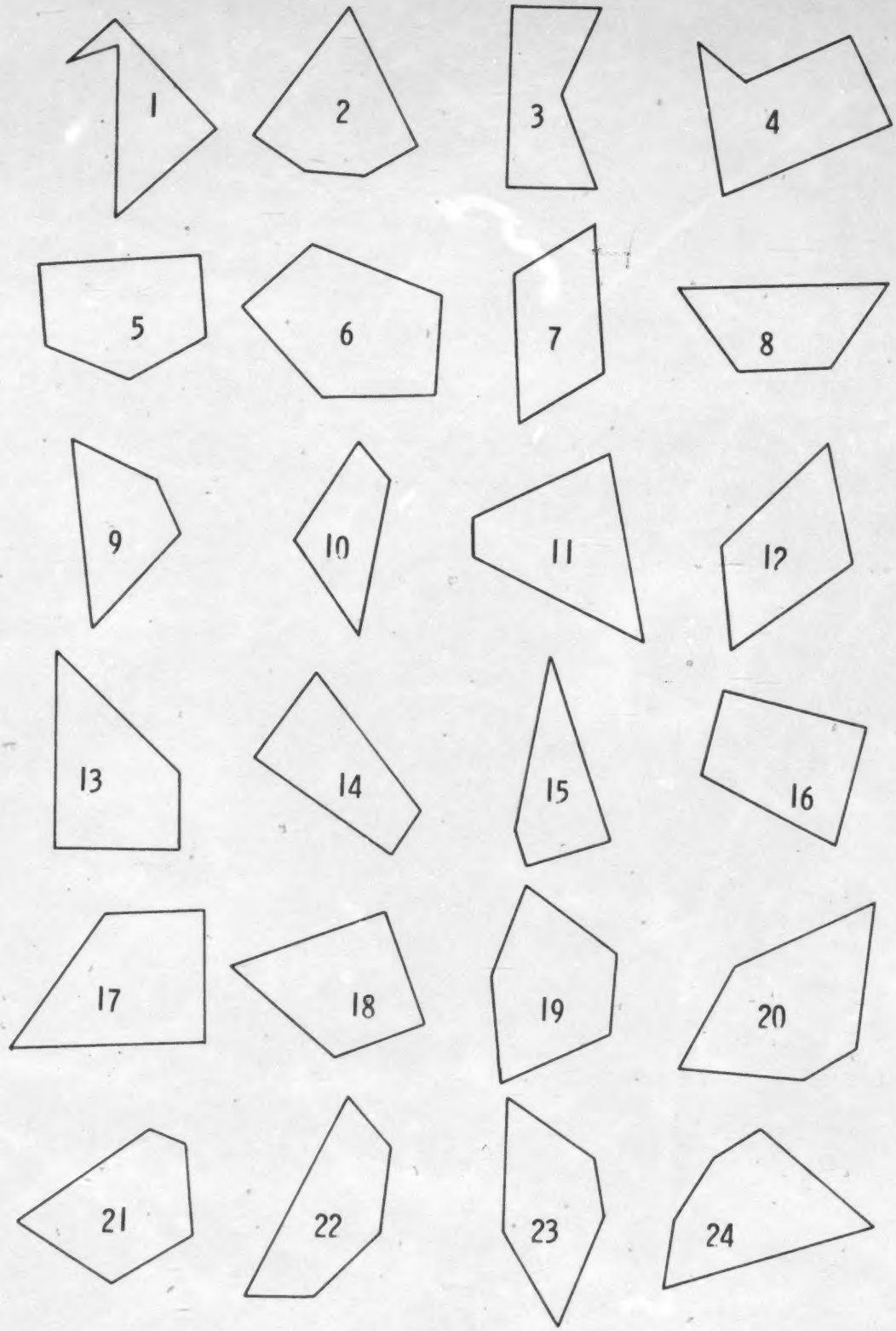

Figure A3. **Geometric figures used in Test 6 – concept identification.**

☆U.S. GOVERNMENT PRINTING OFFICE: 1976- 671-602/8044 43